

NIGERIAN COMMERCIAL SECTOR MARINE BOARD WOOD COMPOSITE HARDNESS ASSESSMENT

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Abstract: Technical insights on hardness test analysis on marine board plywoods in Nigerian market needed by stakeholders to prevent loss of revenue that may arise due to choice of indecorous marine board plywoods for abundant needs as a result of non-availability of such data was investigated. Most frequently sought after marine board plywoods were identified, out of which the top three were subjected to test after selection to establish their hardness. Each of the samples as required by the Leeds Hardness Tester was prepared and tested four times on the machine for a mean. Plots on the hardness of the samples were ensued by computer program from the generated data. Results show that Marine Plex attained aggregate average hardness of 364.5 Leeds Hardness Test (HLD), Super-Plex attained aggregate average hardness of 370.75 HLD while Nplex attained aggregate average hardness of 392.25 HLD. Statistically, that Nplex is 5.799% and 7.613% harder than Super-Plex and Marine Plex respectively. The difference in hardness between Super-Plex and Marine Plex is small compared to the difference in hardness between Nplex and Marine Plex which is as much as 27.75 HLD. Choice of suitable marine board plywoods based on their hardness would be informed by this novel revelation. In the development of their products, biomedical engineers as well as other stake holders should utilize these results. Future research attention should be geared towards hardness tests of medium-density fibreboard (MDF) and high-density fibreboard (HDF) in Nigerian economy.

Keyword: Indentation Hardness testing, Indentation Testing, Leed Hardness Test, Material Hardness Testing, Material Testing, Mechanical Testing, Rockwell Hardness Test, Scleroscope Testing, Surface Hardness Testing, Vickers Hardness.

I. Introduction

Background of the Study

As noted by (FMRL, 2025) the global plywood market valued at USD 50.2 billion in 2024 is expected to grow from year 2025 with projection to reach USD 74.5 billion by the year 2033 at a compound annual growth rate (CAGR) estimate of 4.5%. In Nigeria, wood composite (plywood) is extensively used across construction,

furniture, and packaging industries in Nigeria, as it remains a vital engineered wood product. Despite abundant raw materials and a fast-growing domestic market, unfortunately Nigeria presently remains heavily dependent on plywood imports. The Nigerian plywood market valued at USD 8.81 billion in 2023 and being on a growth direction is expected to grow at a CAGR of 3.3%, reaching USD 11.05 billion by 2030 as noted by (FMRL, 2025). Asserted by Ogunwusi, (2012), forestry products industrial goods exports in the 1950's, 1960's and 1970's were once enjoyed by Nigeria, even as plywood remains a vital engineered wood product extensively used across furniture, construction and packaging industries in Nigeria. Wood composites, a derivative of wood product are normally obtained through the processes of binding the particles, strands, boards, or fibers of wood together. From vegetable fibers using lignin-containing materials with chemical additives enabling the integration of polymer and wood flour while helping facilitate optimal processing conditions, similar composite products can also be made. Due to an excellent combination of mechanical, thermal and acoustic properties together with a competitive price usually made of materials like rye and wheat straw, sugar cane residue, hemp stalks e.t.c, as observed by (Garcia-Garcia, et al, 2018), particle and fiberboards are widely used in the building industry as eco-friendly solutions to wood with increasing uses in thermal insulators, ceiling boards, wall partitions, e.t.c. Wood composites are engineered to certain specifications resulting in a material that can have diverse applications and this is achieved by the use adhesives. One interesting thing is that wood composites can be created by the use of smaller trees, wood waste materials and hence reduce the need to fell old-growth forests. Studying the production of highly environmentally-friendly fiberboards by hot-press molding using *Posidonia oceanica* wastes and a partially biobased epoxy resin as binder, (Garcia-Garcia, et al, 2018) reveals that there is a remarkable improvement of the mechanical properties with combination of the alkali treatment followed by silanization.

Higher fire hazards could be experienced when wood composite is compared to solid wood products in terms of challenges associated with it as a result of higher chemical heat content and melting properties. Most cheap and common resins usually used in the composites and made with urea-formaldehyde bonded products release toxic formaldehyde in the finished products forming a strong apprehension with wood composite use. Though the process of their manufacture as it relates to solid timber demands for extra primary energy, wood composites have numerous advantages. Additionally is the humidity-induced warping which is not common in solid woods by some fiber-based and particle based composite woods when they are exposed to moisture. It is interesting to note that the demand for wood composite is on the rise as projected by the earlier statistics due to remarkable improvement on esthetic and mechanical properties of the resulting composites, despite all these challenges stated. (Ilo, Ajibo, and Dim, 2025a) opined that failure of form boards frameworks from wood composites (plywood) especially while the concrete is still not yet set shortly after casting of concretes has been a major source of concern to the construction industry.

The purchasing power of the Nigerian currency Naira in the study of inflation trend pattern and its impact on Nigeria's economy according to (Barguma, et al 2022), was seen to be decreasing, a revelation that the

economy especially building materials market is badly hit by the inflation. Following their quest to assess the effect of building materials cost on housing development in Owerri, Imo state, eastern region of Nigeria by (Igboekulie, Monye, and Joseph, 2022), a very strong relationship has been found to exist between building materials prices and rate of residential development. Obaedo, (2024) X-rayed inflation as the most influential factor responsible for increase in the cost of building materials while analyzing the inflation rate and the prices of building materials in Benin city, from a correlation analysis, the prices of the building materials had a direct relationship with the inflation rate in Nigeria thus the cause for the high cost of building materials.

Material Hardness Testing

Any procedure employed to determine a material's resistance to scratching, indentation or even deformation is materials hardness testing. By penetration of another harder material, it is simply a test conducted to ascertain the actual resistance exhibited by materials to permanent deformation. Objectively, material hardness testing is a mechanical test for material properties which are used in materials development, structural analysis and engineering design and development. Usually, it is achieved by pressing a harder material into the surface of the tested material. The size of the resulting indentation which is basically the depth is measured and subsequently converted into a hardness value which indicates how well the material can resist deformation that is permanent. Obviously, a number hardness tests exists. In Brinell Hardness Test, a hardened steel or carbide ball indenter is used to create an indentation on the surface of the material being tested while the Brinell Hardness Number (BHN) is calculated from the measured diameter of the indentation. For very soft materials like plastics to provide quick and easy measurement, Barcol Hardness Test is mainly used. Vickers Hardness Test is employed over a wide range of materials from very soft to very hard ones by the use of a square-based diamond pyramid indenter. Just like Vickers Hardness Test, Knoop Hardness Test uses a rhombic-based diamond pyramid indenter, and is often used for thin films and brittle materials. Shore Durometer measures the hardness of rubber and plastics with the use of a spring -loaded indenter while the Scleroscope measures hardness by the rebound height of a diamond-tipped hammer that is dropped onto a material. Leed Hardness Test adopted in this research is a dynamic impact test that measures the rebound of a small impactor (indenter) to determine the hardness (HLD).

II. Literature Review

Ojo and Idieunmah, (2021) in their research expressed that there is linear relationship between age and strength properties of timber, increasing both the compression and shear strengths and even to a reasonable extent the bending strength. The effect of particle size on the flexural strength, ultimate tensile strength, density and water absorption characteristics of uncarbonized coconut shell/unsaturated polyester composites of particle size 425 microns sample and 170 microns sample were investigated by (Iloabachie, et al, 2017) and the result indicated that maximum flexural and ultimate tensile strength were attained at 20wt% for the 425 microns sample. High mechanical properties were found by (Elbadawi, et al, 2015) when the effect of adding a blend of tannins to commercial urea formaldehyde (UF) on the particleboard made from wood particles of *Acacia seyal* var. *seyal*

using the British Standard European Norm (BSEN) relevant standards as compared to the ones produced by solely urea formaldehyde (UF). The mechanical properties tests results were found to show that flexural strength and elongation at break increased as coconut shell proportion got increased when (Iloabachie, et al, 2018) studied the effects of carbonized coconut shell (CS) volume fraction on mechanical properties of unsaturated polyester resin (UPR) composite. Tensile strength of Teak Wood Saw Dust – Cashew nut shell liquid resin composites was studied by preparing a composite material using a hand layup technique by varying the quantity of the Cashew nut shell liquid (CNSL) resin and keeping the saw dust quantity constant by simple methodology of just increasing the percentage of (CNSL). According to the ASTM D638, tensile strength test on the composites using a Universal Testing Machine (UTM) by (Ganesan and Valarmathi, 2014) revealed that tensile strength of the sample with the highest percentage of (CNSL) was the highest and that the **tensile** increased with increase in (CNSL). Conclusively, the tensile strength of the composite is improved with the increase in the cashew nut shell liquid (CNSL) percentage. As a result of research recently conducted on experimental analysis of flexural strength of wood composite (plywood) in Nigerian commercial sector (Ilo, Ajibo, and Dim, 2025b) revealed that Viewpoint plywood recorded 4.956 N/mm^2 , Plywood EQ recorded 9.467 N/mm^2 while Caledonian, also a make of plywood in Nigerian market recorded 16.973 N/mm^2 as the maximum stress, modulus of rupture (MOR) each of them can withstand while being bent before failing or rupturing. It was observed that coconut fibre reinforced HDPE has 28.6 mega pascal as optimum value for flexural strength while (Ihueze, Achike, and Okafor, 2016) studied performance characteristics and reinforcement combinations of coconut fibre reinforced high density polyethylene (HDPE) polymer matrixes at optimum condition of volume fractions and particle sizes of coconut fibre-filler.

In a study conducted to test for the potentials of low-density polyethylene (LDPE) such as plastic films from packaging as resins for saw dust from coconut lumber for the production of wood-plastic composite (WPC) particleboard when the boards were prepared from 50%-80% by weight of LPDE to sawdust content, both physical and mechanical properties of WPC evaluated, (Valle, 2020) found that the tensile strength, face screw holding and modulus of rupture meet the minimum specifications of the US standards. Good interfacial adhesion between sawdust particle and LDPE reduced thickness swelling and improving moisture resistance by diminishing hygroscopy hence expanding the utilization of composites from agricultural wastes and plastic wastes for industrial applications, especially in moist environments, even as well as marine use and humid environment was also revealed by the study. Carbonized coconut shell particle reinforced composite recorded the least density value making it desirable in light weight material application through the study by (Iloabachie, et al 2014) on the effects of carbonization on the physical and mechanical properties of coconut shell particle reinforced polyester composite. For both physical and mechanical properties, the panels with 50% CC had the most preferred performances in a study by (Akinyemi. Afolayan, and Oluwatobi, 2016) on the properties of developed composite corn cob (CC) and sawdust (SD) particle boards using 100%, 75%, 50%, 25% and 0% variations for both agricultural wastes using formaldehyde as binder at constant volume. Empty fruit bunch

fibre reinforced polyester matrix composite has the maximum hardness strength of 19.062 N/mm² which depended greatly on the reinforcement combinations of control factors in a study by (Okafor, Ihueze, and Nwigbo, 2013) on the optimization of hardness strengths response of plantain fibres reinforced polyester matrix composites (PFRP) by application of Taguchi robust design. Changes were observed on surface quality after 50 reuses with oriented strand board (OSB) panels formworks while modification of surface quality was noticed after 80 reuses with marine plywood formworks on the study by (Courard, et al, 2012) on evolution of surface properties of concrete through measured lightness and absorption as analysed in the study of panel frameworks.

A higher strength value of medium density fibreboards (MDF) composites samples than plywood composites samples was revealed because of the increasing thickness of the activated carbon filler (by Aziz, et al, 2015) in their study on the influence of activated carbon filler on the mechanical properties of wood composites. Wear behaviours of 9500C carbonized ash were revealed better than those of 8500C and 9000C carbonized ash due to the degree of alteration in the structure of silica by (Ozioko, 2011) upon the analysis of the effect of carbonization temperature on wear rate behaviour of rice husk ash reinforced epoxy composites. SGK Nordic had the best ultimate flexural strength of 13.568 N/mm², Richard Russel had ultimate flexural strength 12.986 N/mm² while MDF Hokusan (MDF) recorded 1.24 N/mm² as noted by (Ilo, Nwanjoku, and Olayeye, 2025) in a study of flexural strength of medium density fibreboard (MDF) wood composite in Nigerian market. Joubert (HDF) recorded 15.604 N/mm², Dabar (HDF) recorded 32.604 N/mm² while Sinoply (HDF) recorded 39.248 N/mm² of their flexural strength at peak when (Ilo, Nneji, and Igede, 2025) studied the flexural strength of high density fibreboard (HDF) wood composite in Nigerian market. Sinoply, Dabar and Joubert recorded their peak flexural strength at 0.7979%, 0.3769% and 0.2473% strain respectively. Ilo, Uro, and Edeh, (2025) Studied the comparative hardness analysis on Nigerian market wood composite (plywood) and found that Caledonian attained aggregate average hardness of 407.5 Leeds Hardness Test (HLD), View Point attained aggregate average hardness of 456.5 HLD while Plywood EQ attained aggregate average hardness of 459.25 HLD with the statistical analysis showing that Plywood EQ is 0.6024% and 12.6993% harder than View Point and Caledonian respectively.

Ekundayo, Arum and Owoyemi, (2022) assessed the flexural strength of glued laminated beams made from local wood species bonded with phenol resorcinol formaldehyde, polyurethane and urea-formaldehyde adhesives and found the values in glulam beams significantly higher than the control (custom wood) especially in edgewise direction.

Clearly, it is certain from the summary of reviewed literature with regards to their hardness that research has not been directed towards providing technical information on hardness of marine board wood composite in Nigerian economy, hence the need for the research in this area.

III. Research Methodology

Material

Research was made in Nigerian market on commonly used and major marine board plywoods in the Nigerian market. From the survey made, most common and three major marine board plywoods in top demands in Nigerian market were identified. They were selected as samples for analysis. The marine board plywoods samples were Super-Plex, Marine Plex and Nplex. They are represented accordingly in table 1.

In table 1, the samples are coded “ $\alpha\epsilon$ ”, “ Ωf ” and “ βg ” representing SUPER-PLEX, MARINE PLEX and NPLEX respectively. They are all prepared according to the requirement by the machine and tested on the machine one after the other.

TABLE 1 Marine Board Plywoods Samples Tested

Sample	$\alpha\epsilon$	Ωf	βg
Make	SUPER- PLEX	MARINE PLEX	NPLEX

Equipment

A portable non-destructive machine for measuring hardness, the Leeds hardness tester as seen in figure 1 which is a type of dynamic hardness test machine was used. It is based on the rebound velocity of usually a small impact body which is the indenter after it strikes the surface of the material. The indenter component of the tester is placed on each sample and device gadget clicked; the indenter pushes to make an indent on the sample. Carefully set according to the requirement by the leeds hardness tester in figure 1, the samples ($\alpha\epsilon$) representing SUPER-PLEX, (Ωf) representing MARINE PLEX and (βg) representing NPLEX were all tested on the machine successively. The Leeds hardness tester indenter pushes forward to make an impact on the sample by indenting on it as it is operated by placing the indenter of the Leeds hardness tester on the sample and clicking the control button. The operation is repeated four times for each sample (make). With computer program, the dynamics of the action of the indenting and the associated resistance, Leed hardness (HLD) plots are generated. Undoubtedly, the plot which is a function of the sample’s composition resulting from their nature shows clearly the relationship between force per unit area and the extent of the impact (indent) in the sample. Analysis of the plots generated are made under results and analysis.



Fig. 1: Leeds Hardness Tester

IV. Results and Analysis

For each of the samples Super-Plex, Marine Plex and Nplex, the results of the tests are shown as plots in figures 2, 3 and 4 respectively. Essentially, the hardness test results in HLD are for the tested samples of the three selected marine board plywoods.

Plots

The figure 2 below is a plot for hardness test result of Super-Plex sample. The first test recorded 365 HLD, the second recorded 387 HLD, the third recorded 379 HLD while the fourth recorded 352 HLD. The aggregate average of the four tests were taken and reported in the figure 5 for a comparative analysis.

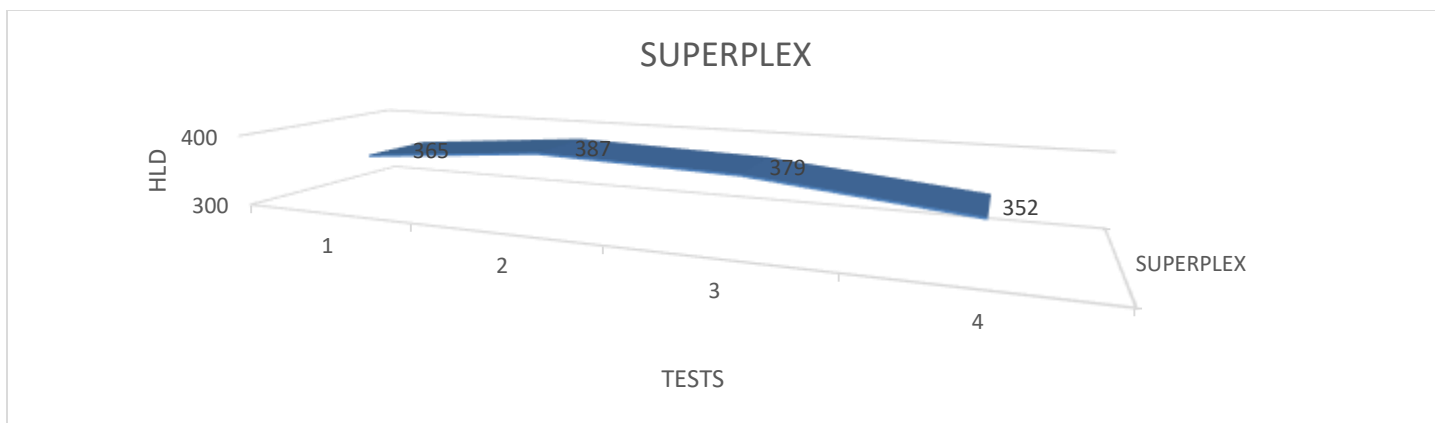


Fig 2: Graph of Hardness Test Results for Super-Plex in HLD

The figure 3 below is a plot for hardness test result of Marine Plex sample. The first test recorded 342 HLD, the second recorded 329 HLD, the third recorded 377 HLD while the fourth recorded 410 HLD. The aggregate average of the four tests are taken and reported in the figure 5 for a comparative analysis.

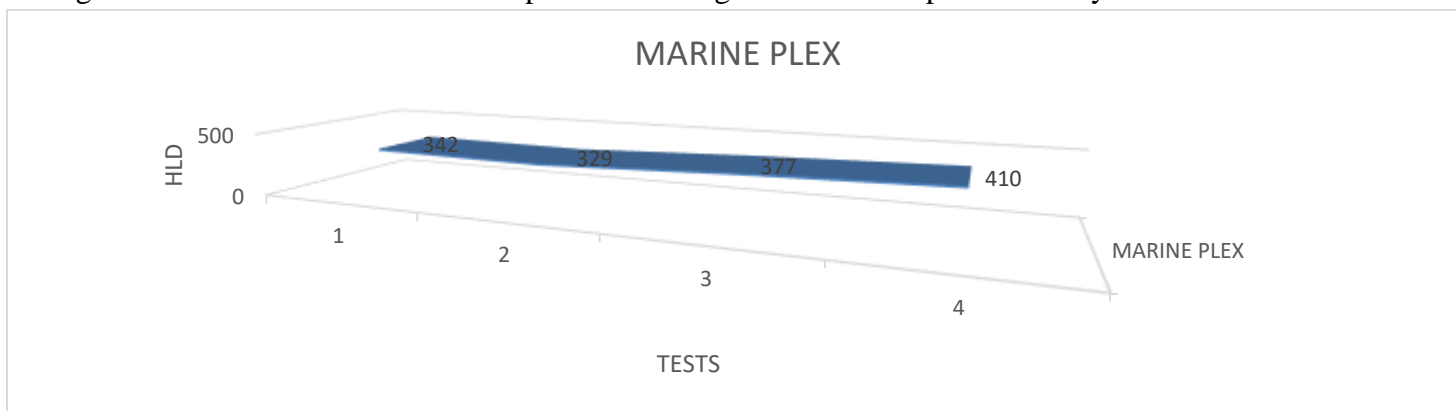


Fig 3: Graph of Hardness Test Results for Marine Plex in HLD

The figure 4 below is a plot for hardness test result of Nplex sample. The first test recorded 401 HLD, the second recorded 416 HLD, the third recorded 381 HLD while the fourth recorded 371 HLD. The aggregate average of the four tests is taken and reported in the figure 5 for a comparative analysis.

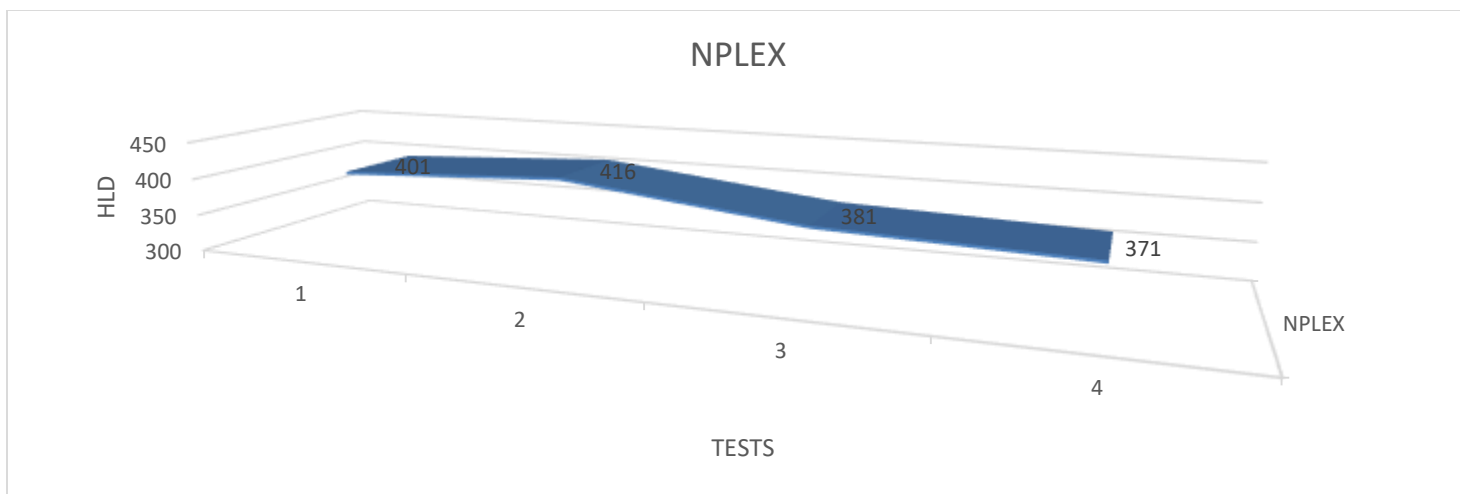


Fig. 4: Graph of Hardness Test Results for Nplex in HLD

The figure 5 below is a plot for aggregate average of the four hardness tests result on Super-Plex, Marine Plex and Nplex samples. Super-Plex recorded 370.75 HLD, Marine Plex recorded 364.5 HLD while Nplex recorded 392.25 HLD.

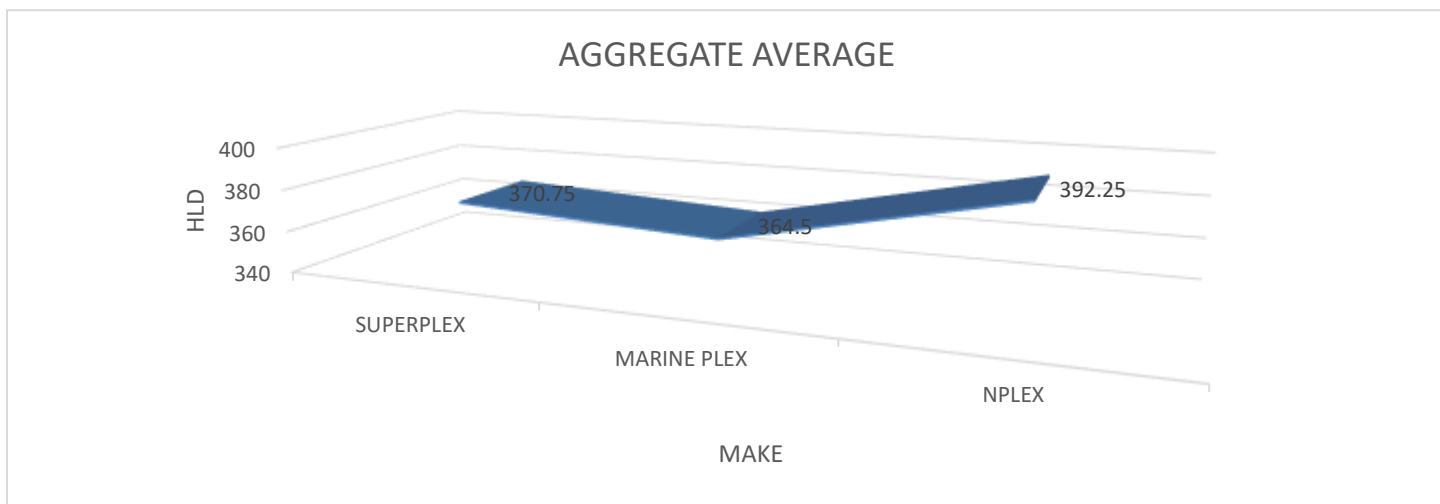


Fig. 5: Graph of Aggregate Average of Hardness Test Results for Super-Plex, Marine Plex and Nplex in HLD

V. Conclusion and Recommendation

In an ascending order of their hardness test results, Marine Plex achieved aggregate average of hardness test result of 364.5 HLD, Super-Plex achieved aggregate average of hardness test result of 370.75 HLD while Nplex achieved aggregate average of hardness test result of 392.25 HLD. Comparatively in terms of hardness, Nplex is 5.799% and 7.613% harder than Super-Plex and Marine Plex respectively. Super-Plex is also 1.715% harder than Marine Plex. These are typically obtained from the result of the tests. This implies that Super-Plex is

harder than Marine Plex while Nplex is harder than Super-Plex. It is worthy to note that the difference in hardness between Super-Plex and Marine Plex is small compared to the difference in hardness between Nplex and Marine Plex which is as much as 27.75 HLD. Depending on application, choice of marine board plywood from Nigeria market can leverage on this novel technical data with respect to their hardness potentials. This Novel technical insight should be valued by architects, building contractors, engineers, individuals, construction companies as well as furniture makers. Biomedical equipment developers can as well utilise this knowledge. Hardness tests analysis of medium-density fibreboard and high-density fibreboard in Nigerian market should form future research works in wood composites.

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